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WATER REUSE IN THE UNITED STATES

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WATER REUSE IN THE UNITED STATES

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Environmental Protection Agency
Washington, D. C.

Thank you Mr. Chairman, ladies and gentlemen. I understand that the opening session of this conference represents something of an innovation with the introduction of a discussion of Environmental Quality: Evaluation and Research. This is most fitting and appropriate since this is the Fifth Annual Conference on Environmental Toxicology sponsored by the Aerospace Medical Division of the USAF and directed towards a discussion of traditional areas of mammalian toxicology. I am happy and privileged to have been invited to address you in an area of environmental quality which is taking on greater significance each day. This is the area of water reuse. I shall direct my remarks more particularly to water reuse in the United States.

"Water, water, everywhere, nor any drop to drink." When Coleridge first authored these famous words during the early nineteenth centry he was naturally referring to the ocean, since at that time the concept of water pollution must have been almost unknown. Today water pollution is not only well established, but it has become an alarming reality which could, if not checked in time, obtain a stranglehold on the social and economic progress in industrialized countries.

The demand for water is increasing both through population growth and changing life styles brought about by advancing technology, while the supply of water from nature remains basically constant from year to year. This is not to imply that we are or will shortly be out of water, although water shortages are of great concern in some areas. Rather, we must recognize the potential for the use and reuse of wastewater where possible.

There is a growing interest in wastewater reuse in the United States. This is particularly true in water short areas of increasing water demand resulting in depletion of good quality natural water sources.

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With the increased level of indirect water reuse occurring in this country, and an expanding pressure for direct potable reuse of wastewater, many of the active organizations concerned such as the American Water Works Association and the Water Pollution Control Federation are now addressing themselves to this problem in an official way through the formation of a joint committee. In addition there are groups within certain Federal Agencies, such as the EPA Water Supply Division that are now turning their efforts towards the area of water reuse.

Consensus among individuals in the fields of public health, wastewater utility management, engineering, and the university sectors as laid out by the WPCF-AWWA Joint Committee is that the following represent the more pertinent aspects of water reuse:

1. Ever greater amounts of treated wastewaters are being charged to the waters of the nation and constitute an increasing proportion of many existing water supplies.

2. A large number of proposals are being made to introduce reclaimed wastewaters directly into various elements of domestic water supply systems.

3. Sound management of our total available water resources must include consideration of the potential use of properly-treated wastewaters as part of drinking water supplies.

4. There is insufficient scientific information about acute and long-term effects on man's health resulting from such uses of wastewaters.

5. Fail-safe technology to assure the removal of all potentially harmful substances from wastewaters is not available.

6. Federal support is required for an immediate and sustained multidisciplinary national research effort to provide the scientific knowledge and technology relative to water reuse to assure the protection of public health.

Effective water management seeks to assure that adequate quantities of good quality water are available when needed and where they are needed, at the lowest possible cost. Increased public pressure for more effective pollution control measures over the past decade has served to stimulate reuse of municipal and industrial, agricultural and recreational uses. Water managers faced with the increased cost of improving the quality of wastewater effluents are finding reuse to be an economic alternative to increasing water supply capacity for industrial process and cooling needs. Current public pressure for advanced waste treatment to further improve effluent quality is stimulating more serious discussion of direct reuse for human consumption. This is the ultimate concern of the Water Supply Programs Division of EPA: that is the public health considerations associated with direct reuse of treated wastewater for domestic supply.

The Water Supply Division was transferred from the Public Health Service, DHEW when EPA was formed in December 1970. The then existing authorities and responsibilities of the Division were also transferred. The activities of the Division can be summarized briefly as follows:

> The Division is active in six water-related fields of endeavor. There are programs under way to update the Drinking Water Standards, carry out the provisions of the Interstate Quarantine Regulations with regard to interstate carrier water supplies, and provide an effective basic and applied research program on health effects of intimate contact with water; also to provide specialized technical services regarding public drinking water supplies, advance and implement public health and water supply aspects of water resources and provide consultation on the health aspects of water pollution.

Reuse is usually referred to as "direct" or "indirect." For the purposes of this paper, direct reuse is accomplished by recycling waste treatment plant effluents directly to the water treatment plant. Indirect reuse involves the discharge of effluents to bodies or watersheds where it becomes available for use again.

In a recent article, Wolf (1971) observed that the concept of wastewater reuse is not new. People have long been aware that some cities discharge sewage to water sources upstream of other cities' water supply intakes. He cites the extreme case of emergency reuse at Chanute, Kansas in 1956 and 1957 where chlorinated secondary treatment plant effluent was recycled through a dried up river bed back to the city's water intake. The process was primitive by today's technology and the product was objectionable due to turbidity, odor-taste and foaming, but the water reportedly contained no detectable pathogenic organisms. However, other reports indicate that the citizens used bottled water and other sources for drinking.

McCallum (1962) reported the concept of direct wastewater reuse to be technically and economically attainable and he urged engineers, chemists and bioscientists to work together to make it so. He may have overlooked some of the pertinent public health considerations involved or may have been premature in his assessment at that time because Berg (1971) seemed to disagree. Discussing the transmission of virus to humans by the water route he says, "Investigation of the problems of viruses in water is in its infancy. The major problems of what waterborne viruses are important to us, how they can be quantitatively detected and identified in waters of all qualities, how effectively treatment processes remove them, and how they can be destroyed in waters of all qualities are still unanswered. The resolution of all of these problems will mark the direction of research in this area for the next decade."

In March, 1973 the Environmental Protection Agency issued its policy statement on water reuse which may be summarized as follows:

1. The Environmental Protection Agency supports and encourages the development and practices of successive wastewater reclamation, reuse, recycling and recharge as a major element in water quality management, providing the reclamation systems are designed and operated so as to avoid health hazards to the people or damage to the environment.

2. EPA recognizes and supports the potential for wastewater reuse in agriculture, industrial, municipal, recreational and groundwater recharge applications.

3. EPA does not support the direct interconnection of wastewater reclamation plants with municipal water treatment plants.

4. EPA not only is continuing to support reuse research and demonstration projects, but now has underway a research program covering a wide spectrum of health effects research in this area.

In 1971, the American Water Works Association made public its views in the following policy statement:

> The Association believes that the full potential of reclaimed water as a resource should be exploited as rapidly as scientific knowledge and technology will allow, to the maximum degree consistent with the over-riding imperative of full protection of

the health of the public and the assurance of wholesome and potable water supplied for domestic use. The Association encourages an increase in the use of reclaimed wastewaters for beneficial purposes, such as industrial cooling and processing, irrigation of crops, recreation and within the limits of historical practice, groundwater recharge. Further, the Association commends efforts that are being made to upgrade wastewater treatment, and to improve quality before discharge into sources of public water supplies.

The Association is of the opinion, however, that current scientific knowledge and technology in the field of wastewater treatment are not sufficiently advanced to permit direct use of treated wastewaters as a source of public water supply and it notes with concern current proposals to significantly increase both indirect and direct use of treated wastewaters for such purposes. It urges, therefore, that immediate steps be taken, through intensive research and development ... to advance technological capability to reclaim wastewaters for all beneficial uses. Such research and development is considered to be of greater national need than that now being directed to desalinization. It should:

1. Identify the full range of contaminants possibly present in treated wastewaters which might affect the safety of public health, the palatability of the water and the range of concentrations.

2. Determine the degree to which these contaminants are removed by various types and levels of treatment.

3. Determine the long-range physiological effects of continued use of reclaimed wastewater, with various levels of treatment, as the partial or sole source of drinking water.

4. Define the parameters, testing procedures, analytical methodology, allowable limits, and monitoring systems which should be employed with respect to the use of reclaimed wastewaters for public water supply purposes.

5. Develop greater capability and reliability of treatment processes and equipment to produce reclaimed water of reasonably uniform quality in view of the extreme variability in the characteristics of untreated wastewaters.

6. Improve the capabilities of operational personnel.

The concern expressed here is valid from a public health standpoint. Fundamental to the problem is the fact that, with existing technology, there is no economical process available to remove all contaminants in a single step. Wolf (1971) observes that such a degree of treatment, to remove "everything," is not being proposed because economic considerations make it impractical.

We repeatedly see references to articles proclaiming that sewage has been treated to such a high degree that it meets Drinking Water Standards. Wolf condemns such statements as inaccurate. He points out that what is meant is that they meet "some of the requirements of the Drinking Water Standards." There are two paragraphs (the first two definitions, in fact) in the Drinking Water Standards that are very much a part of those Standards. The requirements set up in these paragraphs must be met in order to render the judgment that a specific product water "meets Drinking Water Standards." The first refers to "adequate protection by natural means" which "involves one or more of the following processes of nature that produces water consistently meeting the requirements of these Standards: dilution, storage, sedimentation, sunlight, aeration, and the associated physical and biological processes which tend to accomplish natural purification in surface waters, the natural purification of water by infiltration through soil and percolation through underlying material and storage below the groundwater table."

The second paragraph is concerned with "adequate protection by treatment" which means "any one or any combination of the control processes of coagulation, sedimentation, absorption, filtration, disinfection, or other processes which produce a water consistently meeting the requirements of these Standards. This protection also includes processes which are appropriate to the source of supply; works which are of adequate capacity to meet maximum demands without creating health hazards, and which are located, designed and constructed to eliminate or prevent pollution; and conscientious operation by well-trained and competent personnel whose qualifications are commensurate with the responsibilities of the position and acceptable to the Reporting Agency and the Certifying Authority."

Since "adequate protection by treatment" has not been defined by EPA, which is the Certifying Authority referred to, there are no such waters that "meet Drinking Water Standards." It can, therefore, be stated that the Standard is also similarly questionable if it is to apply to a source water when that source water is sewage.

The 1971 recommendation of EPA's technical task force on the revision of the Drinking Water Standards states in part that, "These Standards apply to a water supply that has been obtained from the most desirable source and are not intended for application to wastewaters effluent, used directly as a raw water source." We must remember that the Drinking Water Standards were developed to be used in connection with a sanitary survey which would assure that the source was relatively unpolluted. The Standards have never taken into consideration the possible toxic elements and compounds likely to be found in wastewaters.

In the field of public health engineering two principles are fundamental:

1. Innovation must be considered suspect until proven safe. We must assume that the reuse of wastewater for human consumption poses health hazards until proven otherwise.

2. Prevention of illness or disease, not the cure, is the objective. Borderline "safe" operations are not acceptable: there must be adequate margins of safety continuously maintained. For each innovation, there must be thorough pilot and field testing demonstrations, development of failsafe monitoring techniques and controls and provision of standby equipment and procedures.

The classic example cited by advocates of direct reuse for potable water supply is the facility in operation at Windhoek, South-West Africa. Effluent from a 1 mgd advanced waste treatment plant is directly recycled for human consumption. The successes in South Africa have received international acclaim. However, it is significant to note that the top scientists in South Africa in the fields of virology, bacteriology and chemistry have complete control over the operation of the facility. Public utilities in the United States cannot afford the use of full time expertise of that stature.

Long and Bell (1972) outline some of the key health factors to be considered which include viruses, bacteria, other microorganisms, chemicals and the reliability of plant operation. They point out that the endemic threat of viruses derives from certain key factors:

1) The infectious dose of viruses is very low: recent studies using vaccine strains of poliovirus, indicated that one Plaque Forming Unit (PFU) taken orally would infect 30% of the experimental group.

2) Clinical illness is observed in only a small fraction of those who become infected: the ratio of clinical cases to subclinical infection ranges from 1:10 to 1:1000 depending on the species of virus involved. Subclinical infections of enteric viruses in man cannot be considered as innocuous to health; in addition, certain enteric viruses are associated with serious delayed effects on the infected persons or even their children. Coxsackie viruses have been incriminated as teratogenic agents and the affinity of these viruses to heart tissue has become increasingly recognized from experimental studies as well as clinical and epidemiological observations.

3) One strain of virus may produce illnesses with widely different incubation periods and clinical manifestations: for instance, a Coxsackie virus may produce meningitis in one person, mycocarditis in another and diarrhea in a third. Obviously, this factor would additionally complicate the epidemiological identification of waterborne source of viral infection.

4) The killing rate of chlorine for different viruses is variable and generally much slower than for bacteria. Recent work by Liu (1971) of the Water Supply Research Laboratory has demonstrated this variability and has also provided leads for other interesting questions on virus behavior. One experiment showed that, for the same degree of kill with the same concentration of chlorine it took 2.7 minutes for a reovirus and 36.5 minutes for the Type II poliovirus. Liu (1971) has also shown that the rate of inactivation for several viruses decreased during the latter part of the inactivation period: theoretically this may be related to the occurrence of virus-clumps or viruses absorbed on particles which would be a likely occurrence in nature (wastewater) and would appear to be more resistant to inactivation.

Against this variability background for inactivation by chlorination and the low infectious dose rate, together with the physiological factors of subclinical infection and pathological variations resulting from the same viral exposure, it can be seen that considerable health damage may be occurring from viruses in drinking water without being readily identified. We call this the "ripple" effect.

Long and Bell (1972) illustrate the point with the following hypothetical situation:

- A tertiary waste treatment plant with 99% virus reduction discharges one to seven virus units per 100 ml.
- With adequate chlorination for a 99.99% reduction of virus, there still is at least one PFU per 50 gallons (or 1×10^6 units in a 50 MGD supply).
- This is the kind of supply many advocate for reuse with no additional treatment.
- With 0.2% of the total supply ingested as drinking water - and a 30% infection rate.
- Up to 600 people would be impacted with a variety of clinical and subclinical infections daily.
- If they in turn shed their viruses through personal contact throughout the community, each case can create a "ripple" affecting may people through a "non-water" route.
- The actual waterborne infection being no more of an order-of-magnitude than the tip of an iceberg represents the whole.

The problem of viruses is especially difficult to deal with since their action is so insidious and the ramifications of their subclinical damages are so pervasive. Much of the chronic ill-health in the nation may be related to low viral infectivity and water is a potential prime route for such infection.

These facts and logical speculations give rise to concern not only for the direct reuse of renovated wastewater but also for the effectiveness and safety of current practices for treating and delivering drinking water.

A second group of concern is bacteria. Examination and extrapolation from data obtained on fecal coli and streptococci in advanced waste treatment studies shows that treatment prior to chlorination should remove salmonellae and other enteric pathogenic bacteria to the same extent that viruses are removed; further that subsequent chlorination will be more effective in destroying these bacteria than the viruses.

However, unusual circumstances and breakdowns can occur and bacteria may not be so simply handled. Recent studies of hospital infection outbreaks have demonstrated that non-enteric bacteria can, under certain circumstances and in sufficient concentrations, present health hazards. Further, two types of these bacteria, the flavobacteria, (involved in four cases of septicemia following open-heart surgery) appear to be resistant to chlorination and can multiply greatly, given time and an appropriate medium.

When these findings are joined with the knowledge that potential elements of advanced wastewater treatment processes may harbor and facilitate the multiplication of bacteria and that recycling may serve to preserve and increase the bacterial seed, one has reason to investigate and handle bacterial aspects with caution. For example, bacterial growth occurs on dialysis and osmosis membranes, ion exchange columns and carbon columns; if these growths should include colonies of chlorine-resistant bacteria such as flavobacteria, then the reclamation plant and the reuse process could serve as a promoter of these infectious agents rather than as a barrier to them.

A variety of other organisms occur in wastewaters and can cause health damage. Prominent among these are protozoa, some of which are resistant to chlorination and have been implicated in the parasitization of the throats of children, and in cases of cerebromeningitis. Free nematodes have been found in municipal water supplies and can serve as carriers for enteroviruses, salmonellae and shigellae.

Lastly, helminth infections have been spread by the practice of utilizing wastewaters for the watering of gardens and lawns; ascaris, trichuris and even hookworm infection may be spread in this manner. Severe and extensive infection of ascaris and trichuris occurred in several European countries in the post World War II years from irrigation of vegetable gardens with sewage effluent; the residents of Munich, Germany were hit worst. Effluent irrigation of pastures has also been shown to infect cattle with beef tapeworm, which in turn, could infect man.

Studies relating to the health aspects of wastewater reuse should consider helminth infections in recreational bathing projects and both protozoan and helminth infections in reuse for the irrigation or processing of food crops.

Chemicals in drinking waters may exert acute or chronic effects on humans. We all are aware that the home today is a veritable chemical depository, and the sewer in turn acts as a ready receptacle for disposal of all these materials. In addition, a great variety of activities within the community contribute to a considerable degree to the use of the sewer as a chemical dumping ground. When we consider the universal availability of many highly toxic substances, some concern should also be directed towards the possibility of deliberate sabotage or accident to our water supplies. Some thought should be given to a holding period prior to reuse along with a continuous monitoring program which includes some type of bioassay of the renovated waters. Without this, any immediate and direct reuse of renovated wastewaters will continuously expose the public to hazards from accidental or malicious spilling of toxic chemicals into the sewer system. The extent of the problem can be partially demonstrated by using actual reported data for toxic chemicals entering the Ohio River Basin since 1969. Over 2 million gallons of such exotic chemicals as vinyl cyanide (3,800 gallons), phenol (2,700 gallons), 2-4 toluene di-isocyanate (11,000 lbs), and 17,500 pounds of "assorted organic chemicals" entered the river. Similar spills (and dumps) obviously occur in many cities and reach the sewage treatment plants and pass through such process unaltered. Most treatment processes in use today have little effect on the removal of these chemicals.

In the case of the disposal of chemicals via the sewer as compared with that dumped into rivers, the volumes of contaminants may not be as great but neither is the dilution factor. It is currently estimated that only 20% of the spills of toxic chemicals are even reported, and the time period for reported spills has ranged from 1 up to an incredible 36 days during 1971.

Most of the detailed studies of the chronic health effects due to the many chemicals currently found in waters now used by the American consumer have yet to be accomplished, and there is practically no information available on the health hazards of chemicals found in renovated wastewaters. Among the inorganics: mercury, lead, arsenic, chromium, cadmium, nitrate, and cyanide are of extreme importance and have been addressed in the 1962, as well as the 1974 Drinking Water Standards. In addition, many others such as sodium are important to those whose marginal state of health requires certain additional consideration and concern in contemplating the direct use of renovated wastewaters. Among the organics: o-nitrochloro benzene, pyridine, chlorinated pesticides, diphenyl ether, kerosene, nitriles, benzene derivatives, and many others are of extreme concern and require extensive research. Many newer pesticides and herbicides have been added to the list of potentially hazardous chemical pollutants.

Long and Bell (1972) cite a recent report from the Netherlands indicating the formation of a toxic product, methionine sulphoxum, when chlorine is added to water containing ammonia or amino groups and methionine (a compound found in flour mill waste).

Among other chemical aspects requiring attention are such organic compounds as those containing a benzpyrene base and known to be carcinogenic. In addition, potential sex hormone effects resulting from the increasing use of birth-control pills and their residue or by-products which may be returned to sewer systems could also present a problem. Research on wastewater reuse should include characterization and toxicity studies of the recovered organics by carbon filtration, as well as the development of a method or methods to recover those organics that are not removed by carbon absorption. Studies concerned with the identification of these compounds and the determination of their chronic toxicity at low levels and/or their carcinogenic risk are essential. Such studies have hardly commenced as yet. This information is needed in order to develop specific MAL's for these materials.

It is certainly obvious that prior to the intimate use of any wastewater, the chemical characteristics of that wastewater must be determined and adequately monitored in order to assure that no substance of a harmful nature reaches the ultimate user.

In spite of the extensive process developed by AWT facilities thus far, the fact remains that there are harmful metals and organics that will pass through such processes.

In depth toxicological testing of highly treated sewage effluents has not been accomplished; therefore we are not in a position to completely and safely judge the health implications. When such knowledge does become available, we still must develop systems to continuously monitor for these substances.

For the most part, non-biodegradable (refractory) organics are not removed by AWT processes, including the carbon absorption techniques. Some of these organics have been demonstrated to be harmful to health. We do not at this time have all the techniques to isolate, identify, measure, and partition these organics in terms of human health. Therefore, to emphasize our public health principle it is our responsibility to err on the side of caution in any consideration involving the possible introduction of such contaminants into a public drinking water supply.

Of paramount importance is the reliability of water treatment plant operations. For the sake of discussion, let us assume that the correct processes have been developed, validated and installed. What comfort does our knowledge regarding the operation of wastewater and water treatment plants give us pertaining to reliability? At present, very little.

The National Community Water Supply Study (1970) dispelled any reason for complacency in the findings that 36% of 2,600 individual tap water samples contained one or more constituents exceeding the 1962 Drinking Water Standards.

For adequate public health protection, it is clear that we need to accelerate our research and development to provide fail-safe operations, monitoring and control, particularly where drinking water is involved (all, of course, in addition to research for development and validation of processes which can do the job of providing renovated wastewater with no public health threat). A few of the operational principles and features which we foresee are:

1) Provision of standby units in case of unit breakdown most important for disinfection.

2) Provision of a "holding" basin between the wastewater treatment sector and the drinking water intake to allow for monitoring and bioassay prior to reuse.

3) Provision of an alternate means for disposal of the renovated wastewaters in case of long-term breakdown, and

4) Establishment of fail-safe monitoring and warning devices to maintain a continuous control on the system.

In summary I would like to cite the following: Before development of intimate personal contact uses of renovated wastewaters we need to:

1. Continue and expand studies on viruses to:

   a. Develop improved viral detections and enumeration methodology.

   b. Explore and define the basic properties of enteric viruses.

   c. Provide knowledge on transmission of viruses through the aquatic environment.

   d. Define the impact of viral disease on man through associated epidemiological studies.

e. Develop technology for the positive renoval and inactivation of viruses.

2. Investigate the potential for bacterial and other microorganism problems in reclamation systems.

3. Identify and define the potential health effect of organic and other chemicals, not removed by reclamation plants and subject to buildup, and develop techniques to identify and readily measure the concentrations of such chemicals.

4. Dispel the cloud which hangs over the whole subject of reliability for wastewater treatment plant operation. Reclamation plants for direct reuse must have fail-safe processes, backup facilities, alternate means for disposal, continuous monitoring and bioassay and they must be operated in an atmosphere that demands reliability. State programs responsible for the operation of wastewater treatment plants will require upgrading. Pilot and field-scale testing will be required for the validation of processes and practices prior to their widespread use.

5. As a final point, use our common sense; renovated wastewater should not be used for the ultimate personal use, that of a drinking water supply until there is no other practical choice and, hopefully, when it needs to be used, the minimum research will have been completed and the use will be carefully operated and controlled. Meanwhile, in water-short areas, the renovation and reuse of wastewaters for industrial, limited irrigation and other low human-contact purposes should be investigated and advanced.

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